Summary

Interactions among elementary particles in the universe are mediated by four fundamental forces: strong, electromagnetic, weak, and gravitational interactions. While the standard model of elementary particles describes three of these forces, it excludes gravity. In the standard model, the theory of strong interaction is Quantum Chromodynamics (QCD). QCD predicts that under extreme conditions, such as very high temperatures and/or density, a new phase of strongly interacting nuclear matter called quark-gluon plasma (QGP) can exist. In this phase, quarks and gluons are no longer confined within hadrons. It is believed that QGP also existed in the early universe just a few microseconds after the Big Bang, and it may persist in the dense cores of massive astrophysical objects like neutron stars, where lower temperatures but higher densities prevail. To explore the emerging properties of this strongly interacting medium, heavy-ion collisions are conducted at the Large Hadron Collider (LHC). In these collisions, the system experiences initial large transient magnetic fields (**B**) of the order of 10^{15} Tesla due to the relativistically moving spectator protons. This magnetic field, perpendicular to the reaction plane, formed by the colliding nuclei's impact parameter and the beam direction, provides a unique opportunity to investigate novel

QCD phenomena, leading to local parity violation in strong interactions. The presence of this magnetic field, along with non-zero vector and axial currents, results in a collective excitation in the QGP known as the Chiral Magnetic Wave (CMW). CMW induces a finite electric quadrupole moment measurable through charge-dependent anisotropic flow measurements. The experimental signature of CMW is charge-dependent elliptic flow, v_2. Specifically, the normalized difference of v_2 between positive and negative charges, denoted as $\Delta v_2/\langle v_2\rangle$, is expected to exhibit a positive slope (r_2^{Norm}) as a function of the asymmetry (A_{ch}) in the number of positively and negatively charged particles in an event. However, non-CMW mechanisms such as Local Charge Conservation (LCC), intertwined with collective flow, can also contribute to a similar slope. One way to probe this background is by performing similar measurements with v_3, as it is not expected to be affected by the CMW phenomenon. This study investigates charge-dependent anisotropic flow coefficients in Pb–Pb collisions at a center-of-mass energy per nucleon–nucleon collision of $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV to explore the CMW phenomenon. Specifically, the slope of the normalized difference in elliptic (v_2) and triangular (v_3) flow coefficients of positively and negatively charged particles is reported as a function of their event-wise normalized number difference for both inclusive and identified particles. Additionally, using the Event Shape Engineering technique, the fraction of the CMW signal and its upper limit at a 95% confidence level are extracted.

During the evolution of heavy-ion collisions, quarks and gluons undergo a process called hadronization, transforming into colorless hadrons. Once hadronization occurs, the system reaches a specific temperature known as the chemical freeze-out temperature. At this point, inelastic collisions among the hadrons stop, and the yields of stable particles become fixed. Subsequently, after chemical freeze-out, the hadrons continue to interact through elastic scattering, potentially altering the yields and shapes of their transverse momentum spectra. Later in the process, the system reaches a stage where the mean free path of the hadrons becomes much larger than the system size, termed as kinetic freeze-out, allowing the hadrons to move freely to the detectors. The phase between chemical and kinetic freeze-out, characterized by the proximity of the chemical freeze-out and quark-hadron transition temperatures, is referred to as the hadronic phase. The dynamics of this hadronic phase can be explored through measurements of the hadronic decays of short-lived resonances, particles that decay via strong interaction. Within the hadronic phase, the decay products of resonances engage into two simultaneous processes: regeneration and rescattering via elastic or pseudoelastic scattering (scattering through an intermediate state). These processes can lead to modifications in the measured resonance yields. The strength of these processes depends on the lifetime of the hadronic phase, the density of the hadronic medium, the hadronic interaction cross-section of the decay products of the resonances, and the lifetime of the resonances. Investigating the dominance of one effect over the other involves studying the yield ratios of resonances to longer-lived hadrons with the same quark content as a function of collision centrality. Measurements of $K(892)^{*0}$ and $K^{*}(892)^{\pm}$ have been conducted at midrapidity in pp and Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, respectively. These measurements include the transverse momentum-integrated yield, mean transverse momentum, nuclear modification factor of K^{*}, and yield ratios of resonance to stable hadron. Comparisons are made across different collision systems (pp, p–Pb, Xe–Xe, and Pb–Pb) at similar collision energies to investigate the system size dependency of K^{*} resonance production and the effect of hadronic rescattering. Additionally, the yields of K^{*} are utilized to constrain the kinetic freeze-out temperature using the HRG-PCE model.

The QCD theory provides an understanding of how colored quarks and gluons interact through the strong force, leading to the formation of various types of hadronic matter. This encompasses conventional mesons (quark-antiquark pairs) and baryons (combinations of three quarks or antiquarks). In addition to these standard hadrons, there is ongoing interest in investigating exotic states, such as tetraquarks and pentaquarks, characterized by unconventional quark compositions. This study focuses on the measurement of such an exotic resonance, $f_1(1285)$ in ALICE. The measurement includes determining its mass, transverse momentum-integrated yield, and the average transverse momentum. Furthermore, the ratio of the transverse momentum-integrated yield of $f_1(1285)$ to that of pions is compared with calculations from the canonical statistical thermal model to gain insights into the strangeness quark content of $f_1(1285)$.